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UNIVERSITY OF ILLINOIS

ENGINEERING EXPERIMENT STATION

BULLETIN NO. 3 MARCH 1906

# THE ENGINEERING EXPERIMENT STATION OF THE UNIVERSITY OF ILLINOIS

BY L. P. BRECKENRIDGE, DIRECTOR OF THE ENGINEERING EXPERIMENT STATION.

The Engineering Experiment Station of the University of Illinois was established by action of the Board of Trustees, December 8, 1903. It is the purpose of the station to carry on investigations along various lines of engineering, and to make studies of problems of importance to professional engineers, and to the manufacturing, mining, railway, constructional and industrial interests of the state. It is believed that this experimental work will result in contributions of value to engineering science and to the industries of the state, and that the pursuit of such investigations will give inspiration to students and add to the value of the instructional work in the College of Engineering.

The value to the state of the work done by the Agricultural Experiment Station has suggested the possibility of doing work of similar value to the industrial interests of the state. It is believed that Illinois is the first state to establish an engineering experiment station, but there is every reason to believe that many other states will soon move in such a direction. When a number of states have established such stations, it is entirely reasonable to suppose that the federal government may be depended upon to give the same aid to these engineering stations that it now does to the agricultural experiment stations.

## II. Plan of Organization

The organization for directing and guiding the operations of the station consists of a director and a station staff. The staff consists of seven members, representing with the director the heads of the different departments of the College of Engineering. A corps of assistants will be appointed whose entire time will be devoted to the prosecution of such experimental investigations as may be approved by the station staff. Several assistants have already been appointed who have been detailed to take up special investigations under the supervision of some member of the staff. Preparations are being made for other experimental work, and as fast as the necessary apparatus and equipment can be arranged, additional assistants will be put in charge of the work. Encouragement and aid will be given to instructors already employed by the University who desire to take up some line of research work. Whenever such men prove to be successful experimenters and clear writers, some arrangement may be made whereby a part of their time may be devoted to the work of the station and a correspondingly proportionate part of their salary paid from the funds of the station.

## III. Work Already Accomplished

The first work undertaken by the Engineering Experiment Station was an investigation of reinforced concrete and the properties of concrete affecting reinforced concrete construction. The results of this work are recorded in *Bulletin No. 1, Tests of Reinforced Concrete Beams, by Arthur N. Talbot*, which was published as University of Illinois Bulletin, Volume II, No. 1. September 1, 1904. This was one of the first extensive and systematic investigations on reinforced concrete made in this country, and the results aided in clearing up a number of controverted points. While the investigation was carried on largely as senior thesis work, the character of the work and the supervision and planning given to it, together with the method of furnishing materials and apparatus, warrant giving more weight to the results than may usually be given to results of student work. The investigation covered a considerable range. The results on bond between concrete and steel (plain and deformed bars) and on the relation between compressive stress and deformation were of interest. The measured deformations obtained in plain concrete beams showed

that up to the breaking point in tension the modulus of elasticity for tension is practically equal to that for compression, instead of being one-half as great, as had generally been assumed by writers on this subject. In reinforced concrete beams, the action of the steel and concrete during flexure was studied. It was shown that the concrete failed in tension at its usual breaking limit instead of carrying stress to ten times that limit, as had been claimed by some experimenters, and the added stretch in the steel at this point was clearly shown on the diagrams.

Among the results brought out by this investigation were the following: the stages of action during flexure; the accurate determination of the position of the neutral axis; a basis of calculation of resisting moment of beam based upon tension in the steel; the value of an experimental determination of the position of the neutral axis and of the percentage of steel suitable for a given concrete; the effect of elastic limit of steel and of form of bar upon strength of beam. The tests also opened up the field for further experimentation. The publication of the results was received with much interest by the engineering press and the engineering profession. The comments made gave testimony to the thoroughness of the work and to the great interest and value attached to the investigation, as throwing new light on a subject very much in need of scientific data. Requests for Bulletin No. 1 have come from all parts of the world. The investigation of reinforced concrete beams is being continued and experiments on reinforced concrete columns have been started.

*Circular No. 1, High-Speed Tool Steels, by L. P. Breckenridge*, was issued April 15, 1905. In this circular is given a brief review of the results of experiments made by different engineers with this new tool steel. Experiments with high-speed tool steels on cast iron have been in progress at the shops of the mechanical engineering department of the University during the last year. These tests have been carried on by H. B. Dirks, M. E., and constituted the basis for his graduate work.

*Bulletin No. 2, Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and H. B. Dirks*, giving the results of these experiments, was published in January, 1906. These tests were made with eight different brands of tool steel on cast-iron test pieces of varying hardness. The hardness of these test pieces was obtained by the use of a twist drill weighted to a known pres-

sure and run at a constant speed, the degree of hardness being based on the depth to which the drill would enter in a given time.

The work was divided into several sets of tests, viz., preliminary trials; skin-cut trials; endurance trials; trials to obtain the durability of the steel at different cutting speeds on cast iron of constant hardness; and trials to obtain the durability of the steels on cast iron of varying hardness. Tables giving in full the results of these different tests are supplemented by plates showing graphically some of the following relations: cutting force on point of tool and area of cut for cast iron of varying hardness; durability of tool and cutting speed for cast iron of varying hardness; cutting speed in feet per minute and hardness of cast iron.

From the last mentioned it was found that all the steels tested can remove very hard cast iron at 25 feet per minute, that all steels begin to wear rapidly at speeds a little above 125 feet per minute, and that between these two points there seems to be a definite relation between the hardness of the iron and the cutting speed. The general results show that there are great possibilities ahead for high-speed steels. Tool steels are now available that will cut cast iron from two to three times as fast as was possible a few years ago.

*Circular No. 2, Drainage of Earth Roads, by Ira O. Baker*, practically a reprint of *Agricultural Experiment Station Bulletin No. 65*, was issued in February, 1906, for the use of the Good Road Train of the Chicago and Alton Railway Company, at the expense of the latter.

Experiments are in progress under the direction of the department of Civil Engineering on the holding power of the various forms of plain and screw railroad spikes in treated and untreated timber with the view of determining the most efficient method of fastening the rails to the ties,—an important matter since the hard woods are now almost exhausted, and attention must be given to the softer woods.

Experiments on the collapse of boiler tubes are in progress by the department of Physics. For these tests the Bethlehem Steel Company has furnished a hollow nickel-steel tube, twelve feet long, with an internal diameter of five inches, capable of withstanding an internal pressure of 6000 pounds per square inch. A special pump capable of producing a pressure of 15,000 pounds per square inch has been imported for these experiments. The

department is also investigating the subject of measurement of high temperatures, such as are found in boiler and other furnaces used in industrial works. Both recording and optical pyrometers are being studied.

## IV. Character of the Work to be Undertaken

In determining the character of the work which the station shall undertake, the most careful consideration will be given to the needs and the interests of the state. At the same time we shall not forget the debt which Illinois owes to her older sister states or to foreign nations for furnishing freely the results of scientific investigations or experimental determinations, making it possible for Illinois more cheaply to construct its railroads, mine its coal, generate its power, harvest its crops, communicate with its neighbors, and build its factories, its public buildings and its homes.

The work of the station will also be largely determined by the funds and facilities which are available for its work. It will seek the cooperation of all the industrial enterprises of the state, both great and small, and it will give help along those lines that promise to aid the greatest number of its people.

The work of the station should also extend into some fresh fields, seeking to discover new ways and means for economizing energy and materials, for the prevention of waste, for the perfection of labor-saving machinery, for safer methods of travel, and for surer sanitary methods of water supply and sewage disposal.

As an indication of the character of the work which it is proposed to do, the following short titles are given of some of the most important investigations which have been submitted for the approval of the station staff.

### By the Department of Architecture

1. Insulating walls and materials to prevent transmission of sound, heat, dampness, etc.;
2. Resistance of hollow concrete building blocks to transmission of heat, sound, dampness, etc.;
3. Transmission of heat, light and sound through several thicknesses of glass in windows;
4. Comparative strength of wooden beams in tension, spliced in various ways;

5. Strength of compound (flitched) steel and wooden beams;
6. Strength of built-up wooden girders;
7. Syphonage of traps and its prevention;
8. Collection of best plans for small country schools;
9. Collection of best plans for farm houses and buildings.

BY THE DEPARTMENT OF CIVIL ENGINEERING

1. Tests of road-building materials;
2. Tests of angles riveted by one leg;
3. Effects of punching, reaming and boring upon different grades of steel.

BY THE DEPARTMENT OF ELECTRICAL ENGINEERING

1. Advantageous rates of acceleration for passenger and freight service;
2. Loss from braking, and its partial recovery by raising the level of regular stopping points;
3. Increased tractive effort due to winds in various directions;
4. Possible utility of some form of transmission or speed-changing ratio between motor and car for overcoming grades;
5. Economical lighting of large halls;
6. Determination of the minimum candle-feet required for comfortable reading with lamps of different color values;
7. Methods for increasing the time efficiency of long distance lines.

BY THE DEPARTMENT OF MECHANICAL ENGINEERING

1. Experiments with high-speed tool steels (continued);
2. Boiler trials with Illinois coals (continued);
3. Transfer of heat through scaled boiler tubes;
4. Comparative economy of domestic coals for residence heating;
5. The economy of municipal power and pumping plants;
6. Experiments with superheated steam;
7. Experiments with gas producers.

BY THE DEPARTMENT OF PHYSICS

1. Resistance of boiler flues to collapse;
2. Heat conductivity of walls of buildings;
3. Appliances for measuring high temperatures under furnace conditions;

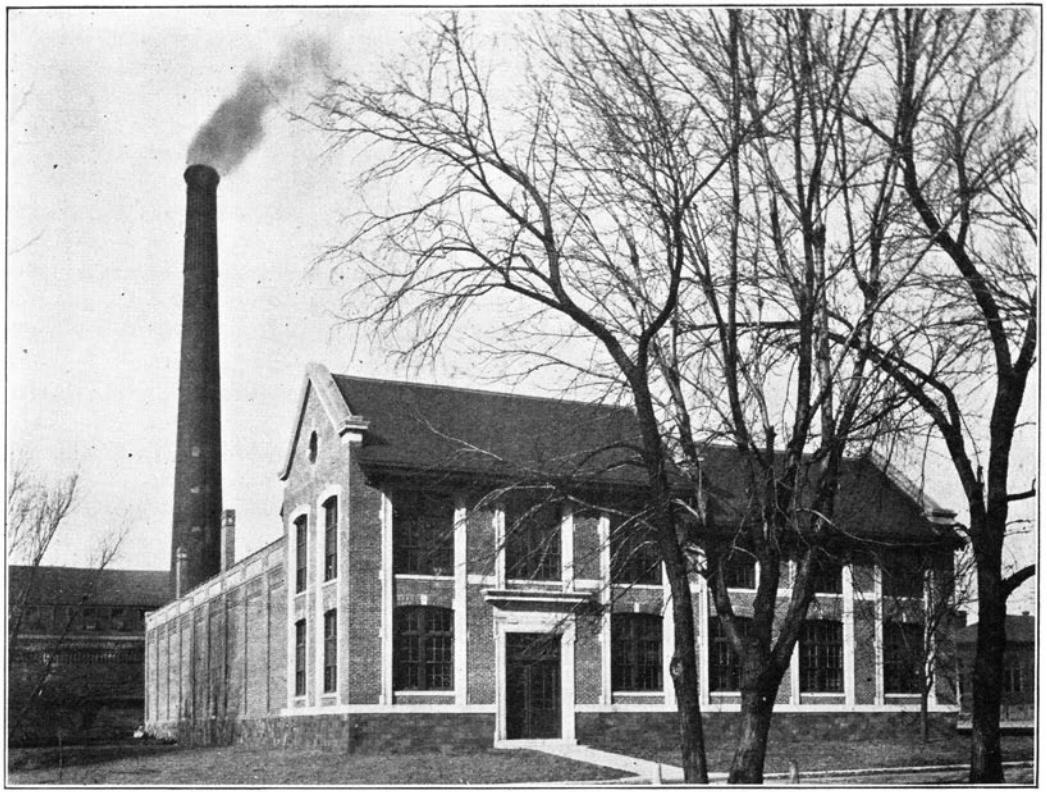

FIG. 1 MECHANICAL ENGINEERING LABORATORY
BUILT IN 1905

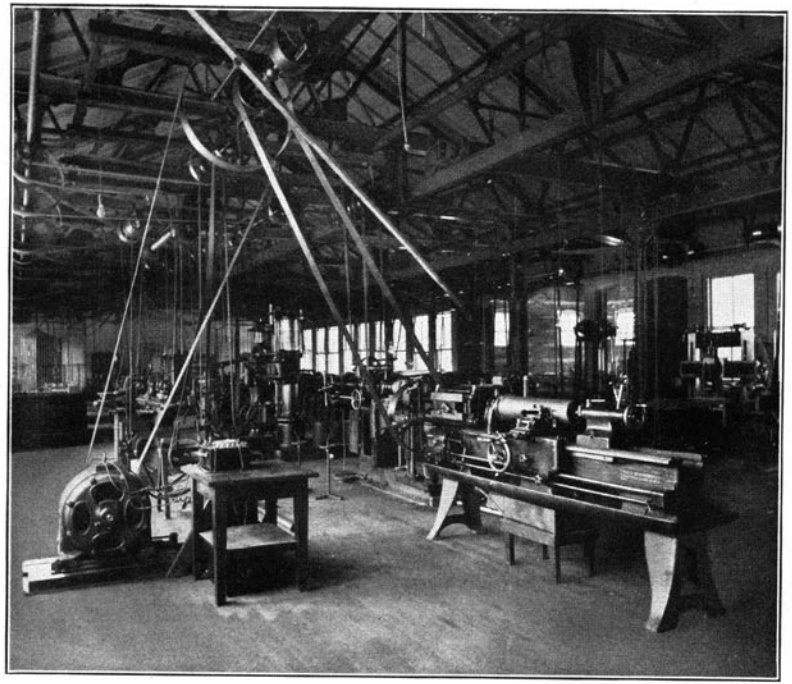

FIG. 2 VIEW IN THE UNIVERSITY OF ILLINOIS MACHINE SHOP SHOWING LOCATION OF LATHE AND MOTOR DRIVE USED IN TESTS WITH HIGH-SPEED TOOL STEELS

4. Determination of vapor densities at very high temperatures and high pressures.

By the Department of Railway Engineering

1. Locomotive road tests and railway train resistance.

By the Department of Theoretical and Applied Mechanics

1. Reinforced concrete beams (continued);
2. Reinforced concrete columns;
3. Timber stringers;
4. Cast-iron columns;
5. A series of tests of interest to manufacturers and railroads on such structures as car bolsters, car frames, wheels, etc.;
6. Qualities of commercial mild steels;
7. A series of investigations on various hydraulic problems;
8. Deep well pumping.

From the above list it will be seen that there exists a very large field for fruitful research. In many cases these investigations must extend over a series of years; in others a few months will suffice for the work.

## V. Facilities For Investigation

The recent rapid growth in attendance in the College of Engineering has made it necessary to extend its equipment considerably, and while the apparatus thus provided is intended primarily for purposes of instruction, much of it is available at certain times of the year for purposes of investigation. Certain appliances have recently been purchased and installed for the especial use of various departments in connection with such investigations as are in progress in these departments.

The Engineering Experiment Station is not quartered in any one building of the College of Engineering, but its work and experiments go on wherever the needed facilities exist in the various departments. Neither is its work confined to the College of Engineering alone. Cooperation with other University departments, such as the College of Science, State Water Survey and with the State Geological Survey enables it to complete many investigations, facilities for which are not available within the College of Engineering. Neither is its work confined within the limits of the University. Cooperation with various departments of the

federal government as well as with many industrial interests of the state is already assured.

On the following pages are mentioned some of the most important appliances which are available for use in various lines of research. Only a few words of description are possible with reference to each. In connection with this article are given several reproductions showing the laboratories in which the investigations are in progress, and also the most important apparatus.

### In the Mechanical Laboratory

1. A 210 H. P. Heine water-tube boiler especially arranged for testing Illinois coals. This boiler is a duplicate of the boilers being used at St. Louis by the United States government in testing coals from various parts of the country. A Green chain grate stoker is installed under this boiler, and draft is furnished by a Sturtevant induced draft fan, drawing the gases through an economizer. The chain grate under the boiler may easily be removed and a plain furnace for hand-firing substituted. A complete equipment of auxiliary apparatus necessary for boiler tests is available, including recording and optical pyrometers, and standard and recording apparatus for continuous gas analysis. Facilities are now available in the department of Physics for calibrating all thermometers and pyrometers used in work of this character.

2. An independently-fired Foster superheater capable of superheating the steam from a 150 H. P. boiler 300° above its temperature at 120 pounds gauge.

3. Several residence heating boilers, for both steam and hot water. These boilers will serve to compare the values of such various coals as are offered in the Illinois market for domestic purposes.

4. A 10-ton York refrigerating plant for the production of cold or for specific tests. With this plant there are 17 cans for ice making, each holding 100 pounds. The possibility of subjecting various building stones or other material to alternate freezing and warming is worthy of consideration. The effect of fifty winters might thus be known in a single month.

5. A liquid-air plant with a capacity of about three quarts an hour. It consists of a Norwalk four-stage compressor, compressing up to 3000 pounds, together with a Hampson liquefier with facilities for temperature determinations.

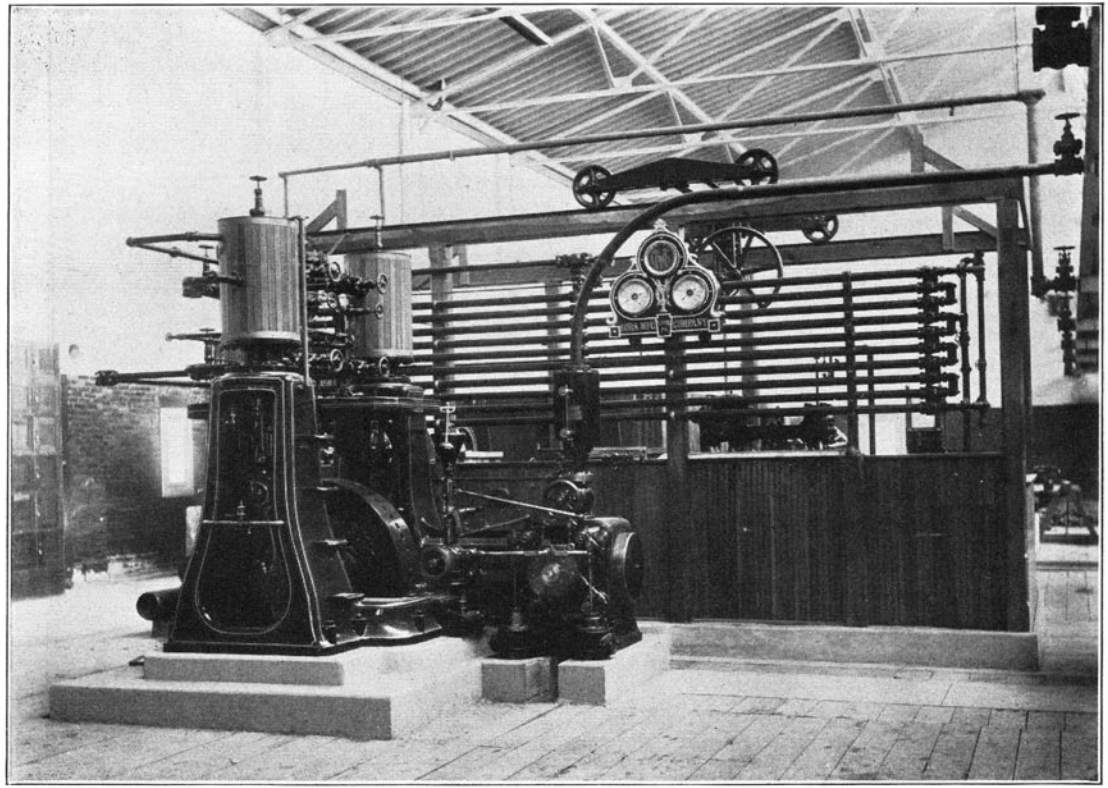

FIG. 3 YORK ICE MACHINE OF 10-TON REFRIGERATING CAPACITY IN MECHANICAL ENGINEERING LABORATORY

FIG. 4 OTTO GAS PRODUCER AND GAS ENGINE IN MECHANICAL ENGINEERING LABORATORY

6. An Ingersoll-Sergeant two-stage air compressor driven by compound steam cylinders. The steam cylinders are 12 inches and 22 inches in diameter with a 12-inch stroke, and the air cylinders are 12¼ inches and 18¼ inches in diameter with a 12-inch stroke. A vertical receiver 42 inches by 8 feet high is provided for use with the compressor.

7. A 50 H. P. suction gas producer built by the Otto Gas Engine Works. This producer is adapted to burning anthracite pea coal, coke or charcoal.

8. An Otto gas engine of 23 brake H. P. capacity for use in connection with the gas producer. The cylinder is 10 inches in diameter, with a 19-inch stroke. It is provided with a compressed air starting device, sparking generator, speed indicators and all other instruments necessary for testing gas engines.

9. A 15 H. P. De Laval steam turbine direct-connected to a compound centrifugal pump. This apparatus will deliver 140 gallons of water per minute when pumping against a head of 500 feet. The turbine wheel and small pump runner make 23,500 revolutions per minute; the large pump runner makes 2350. The turbine is provided with condensing and non-condensing nozzles.

10. A hot blast heating system installed to heat the Mechanical Engineering Laboratory. This consists of a series of coils making 2800 feet of 1-inch pipe and a 72-inch fan draw the air through the coils and force it into the galvanized iron pipe, 36 inches in diameter, which distributes it to different parts of the building. The fan is driven by a small vertical steam engine.

11. A 100 H. P. Allis-Chalmers Corliss engine, equipped with a suitable brake and other apparatus for making tests.

12. Several high-speed steam engines for testing and for driving other apparatus.

13. Several types of gasolene engines, ranging from 1 to 10 H. P., for experimental purposes.

14. An automobile testing platform for testing automobiles.

15. A 10-ton electric crane, having three alternating current motors, for experimental work.

16. A Golden oil testing machine for testing lubricating oils and bearing metals.

17. Apparatus for tests relating to the transmission of heat through scale-covered boiler tubes with respect to the loss due to scale. The equipment now in the Mechanical Engineering Lab-

oratory for determining the loss due to the scale when transmitting heat through scale-covered tubes consists of a boiler and furnace giving approximately practical conditions, also auxiliary apparatus for making the required observations. The furnaces employed are constructed of wrought iron suitably covered, or of brick with fire-brick lining, and are equipped with gas burners for the generation of the required heat. From the furnace the hot gases pass through the tube which is being tested. This tube constitutes the single flue of the experimental boiler. The boiler is filled with water continually entering and leaving at temperatures maintained constant. The auxiliary apparatus used consists of constant-pressure tanks for air, gas and water, suitable thermometers, pyrometers, scales, etc., a Le Chatelier pyrometer being used to measure the temperature of the hot gases entering the tube.

### Railway Test Car No. 17

18. This railway test car is a special car operated for experimental and instructional purposes. It is owned jointly by the Illinois Central Railroad and the University of Illinois. It was built by the railroad company, equipped by the University and is operated for the advantage and information of both. It is considered by the University as a part of its laboratory equipment, and affords facilities for practical railroad tests which could not otherwise be made.

The car is used principally in connection with dynamometer car work, and on this account was built especially heavy in order to withstand the usage incident to this kind of work. It is 45⅛ feet in length. A space of about 15 feet in the rear of the car is occupied by berths and lockers, the remaining space being devoted to apparatus and instruments.

The dynamometer is of the hydraulic or oil transmission type. It consists of three cylinders in tandem, and is situated near the forward end of the car just back of the draft rigging. The dynamometer is suitably connected with a recording instrument which gives the draw-bar pull record upon paper traveling at a rate of speed proportional to the speed of the train. Upon the same paper records are made of time, speed, distance and such other data as may seem desirable. In addition to the dynamometer with its attached recording instrument, paper travel mechanism, gauges and similiar apparatus, the car is equipped with a Boyer speed recorder, a Hausshalter speed recorder, rec-

ording gauges for steam pressures, train line pressures and draft, also with air and steam pressure gauges for various purposes.

In its capacity as a dynamometer car, Railway Test Car No. 17 affords facilities for work along the following lines:

Tonnage rating tests;

Engine efficiency tests;

Tests in relation to engine design and tractive force;

Tests to determine resistance of freight, passenger, loaded or empty cars;

Tests to determine resistance of trains as affected by speed, curves, temperatures, condition of track or special equipment.

Aside from its use as a dynamometer car, when no draw-bar pull record is desired, the car is used in connection with locomotive road tests or other road tests, records being made in the car automatically or otherwise that without the car would not be attempted or could be made only with difficulty. Further the car serves a most useful purpose as office, laboratory and computing room when making railroad or other shop tests in connection with railway work.

This car has already been in extensive use on the Illinois Central Railroad for the purpose of making locomotive road tests, and for establishing tonnage ratings on the various divisions. The preliminary experimental work relating to train resistance in connection with the electrification of the New York Central lines out of the Grand Central Depot, New York City, was all done with this car. A series of tests has also been made with this car comparing the relative draw-bar pull and acceleration factor of steam and electric locomotives on the experimental tracks of the General Electric Company at Schenectady, New York. Both of these tests have been reported to the American Society of Electrical Engineers in a paper by B. J. Arnold at the annual meeting 1904.

### In the Road-Materials Laboratory

The Civil Engineering department in its Road-Materials Laboratory is equipped with apparatus for testing materials for road and pavement construction as follows:

(a) Two types of rattlers for testing brick: National Brick Manufacturers' Association and Talbot-Jones;

(b) A Dorrey, a Deval and a Page machine with the neces-

sary accessories for testing the road-building qualities of gravel and macadam. The laboratory is cooperating with the State Highway Commission and with the State Geological Survey in a systematic study of the road-building materials of Illinois.

### In the Cement Laboratory

This laboratory is equipped with briquette molds, molding machines, testing machines, etc., necessary in testing hydraulic cement, and in making investigations as to the effect of different materials and methods of manipulation upon the strength of mortars and concrete.

### In the Laboratory of Applied Mechanics

1. A Riehle vertical screw power testing machine of 600,000 lb. capacity fitted to take large and bulky test specimens. This machine will take compression pieces 25 feet long and tension pieces of the same net length except as allowance must be made for stretch. The clear distance between screws is 36 inches, which gives room for bulky and built-up pieces. The machine is provided with a stiffened vertical frame to allow eccentric and oblique forces to be applied to test pieces, an unusual feature in testing machines. Short beams may be tested on the machine, and provision may easily be made for testing longer beams. Auxiliary appliances are used for holding the various forms of test piece in order to secure an application or distribution of the load in the manner desired. Especial attention was given in the design and construction of the machine to making it applicable to a large range of tests. The calibration of the machine shows that it is very accurate and very sensitive. For the smaller loads a second poise weighing up to 60,000 lb. is used.

2. An Olsen four-screw testing machine of 200,000 lb. for tests in tension, compression and flexure. This machine will take beams up to a length of 20 feet.

3. Three 100,000-lb. testing machines of different makes, fitted up in the usual way.

4. An Olsen torsion machine of 220,000 inch-pound capacity.

5. An Olsen vibratory testing machine for testing stay bolts.

6. A variety of smaller machines for testing cast iron, timber, etc.

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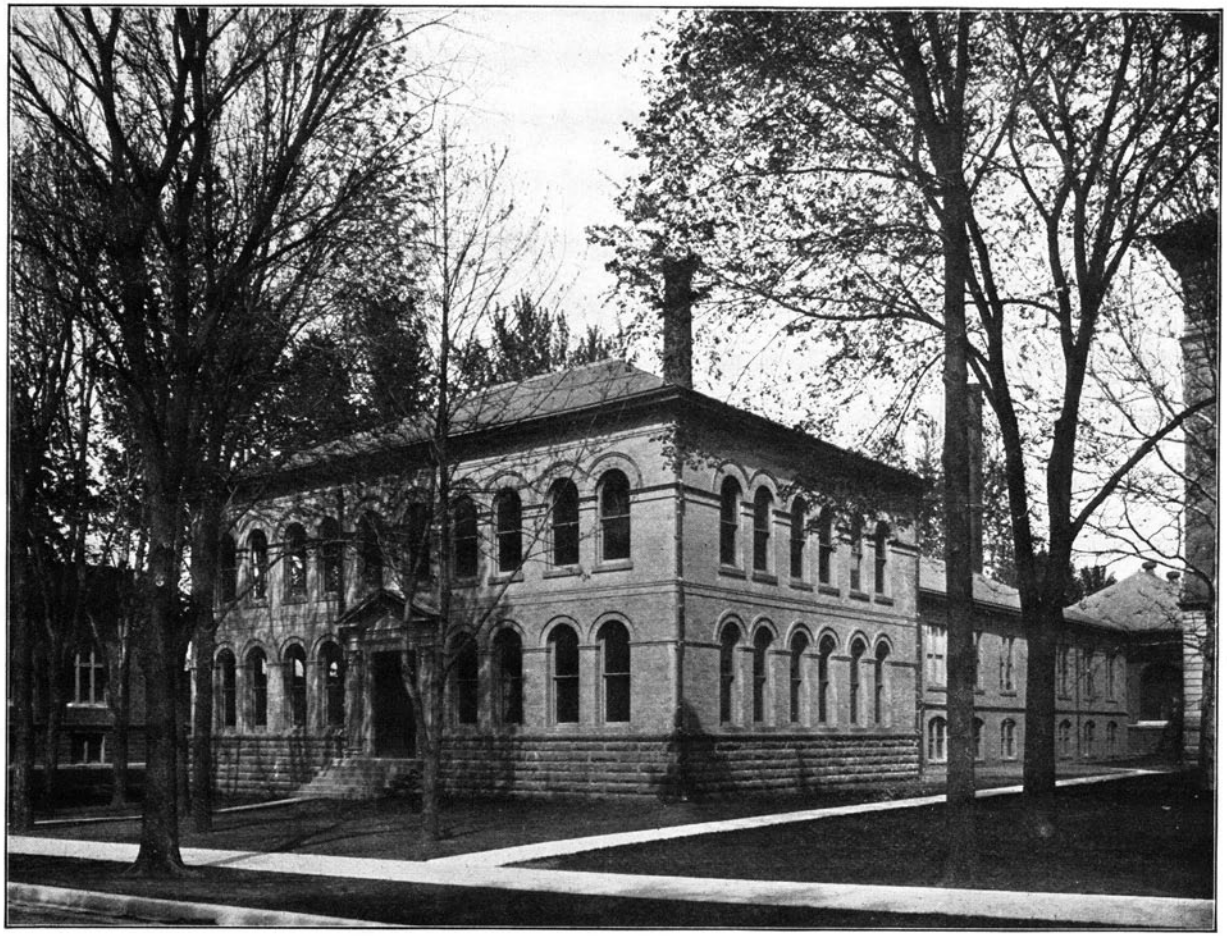


FIG. 5 LABORATORY OF APPLIED MECHANICS
BUILT IN 1901

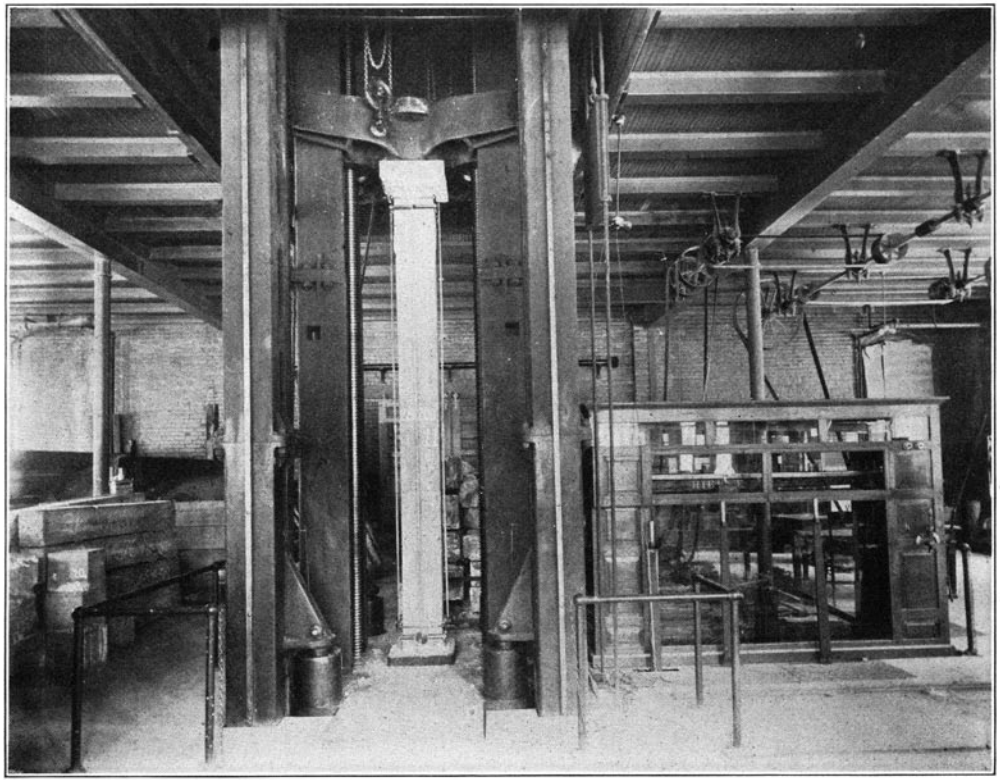


FIG. 6 TESTING 12 x 12 IN. CONCRETE COLUMN IN 600,000-LB. TESTING MACHINE

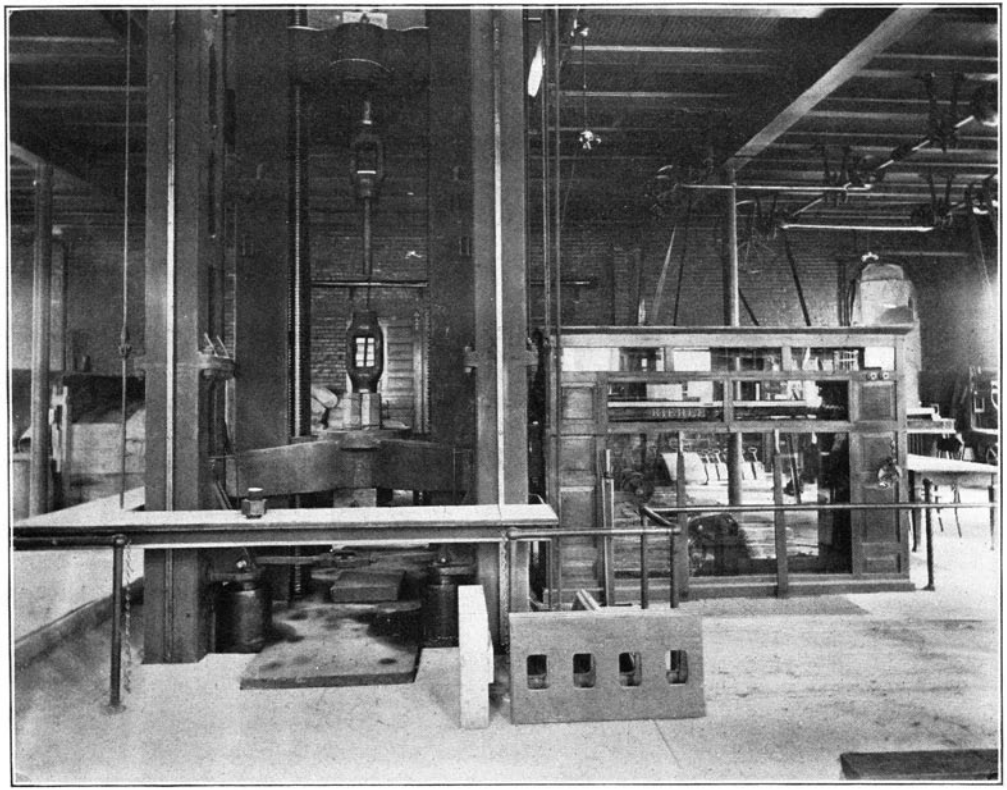


FIG. 7 VIEW SHOWING 600,000-LB. TESTING MACHINE AS USED IN TENSION TESTS

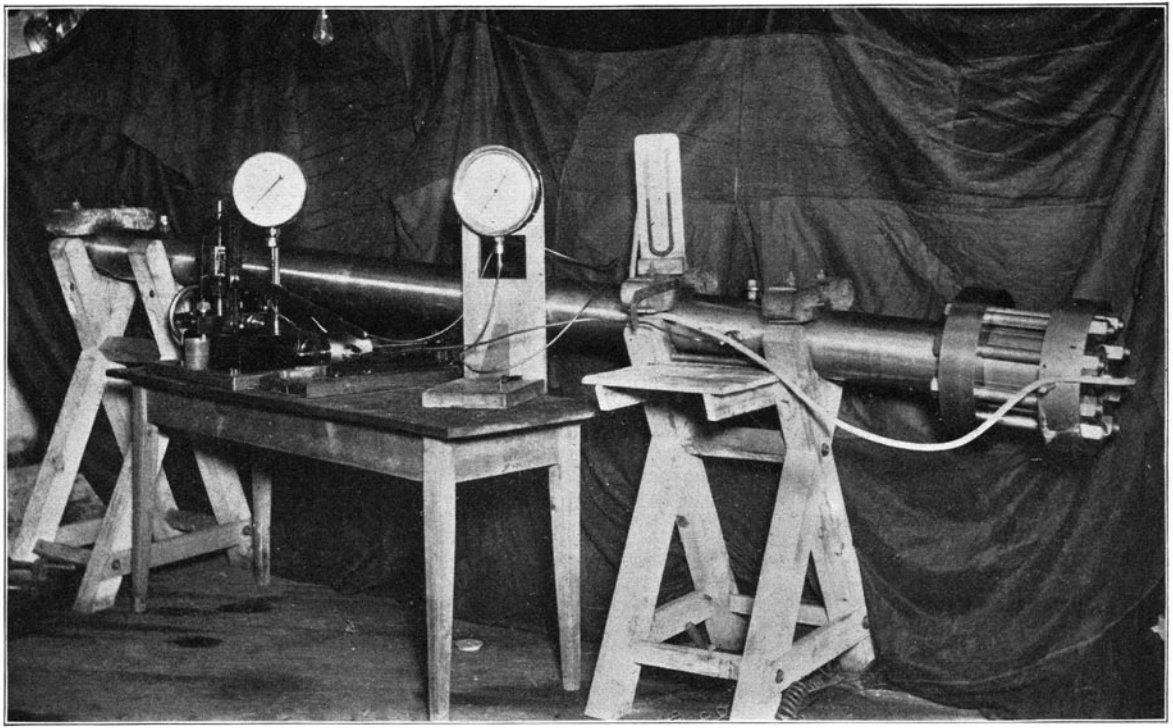
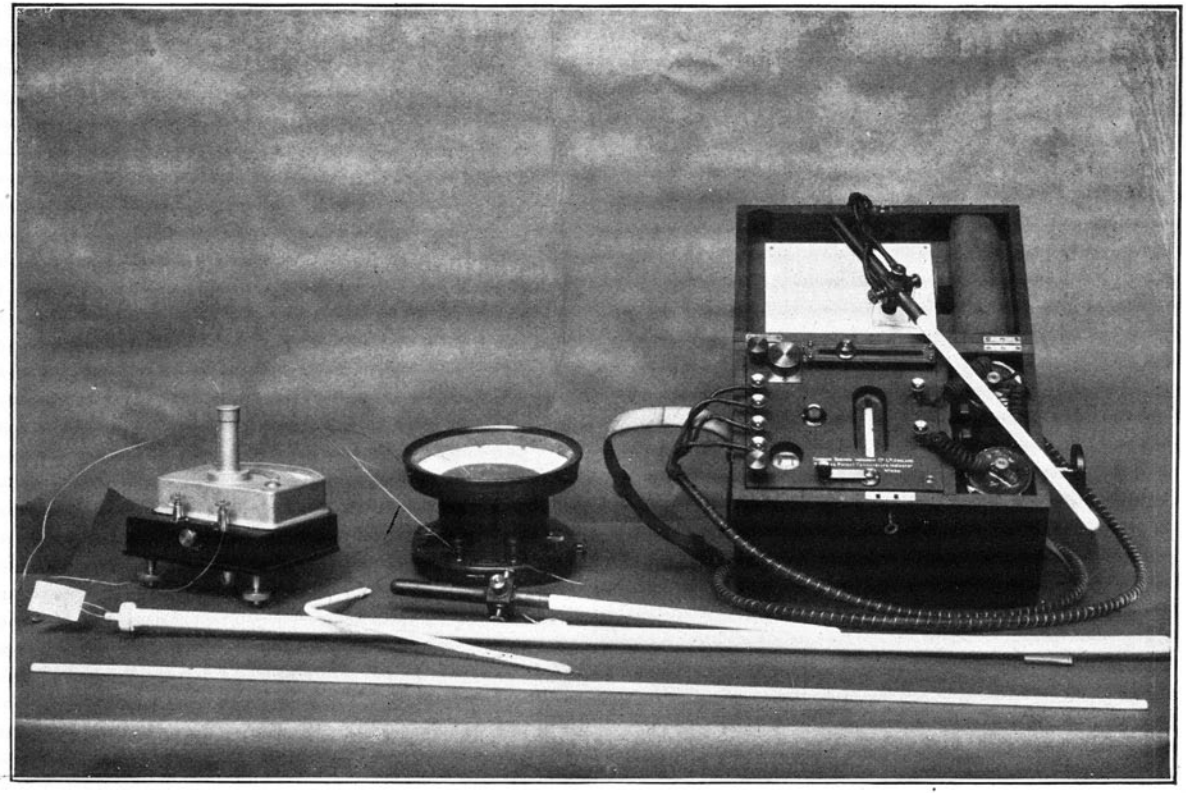
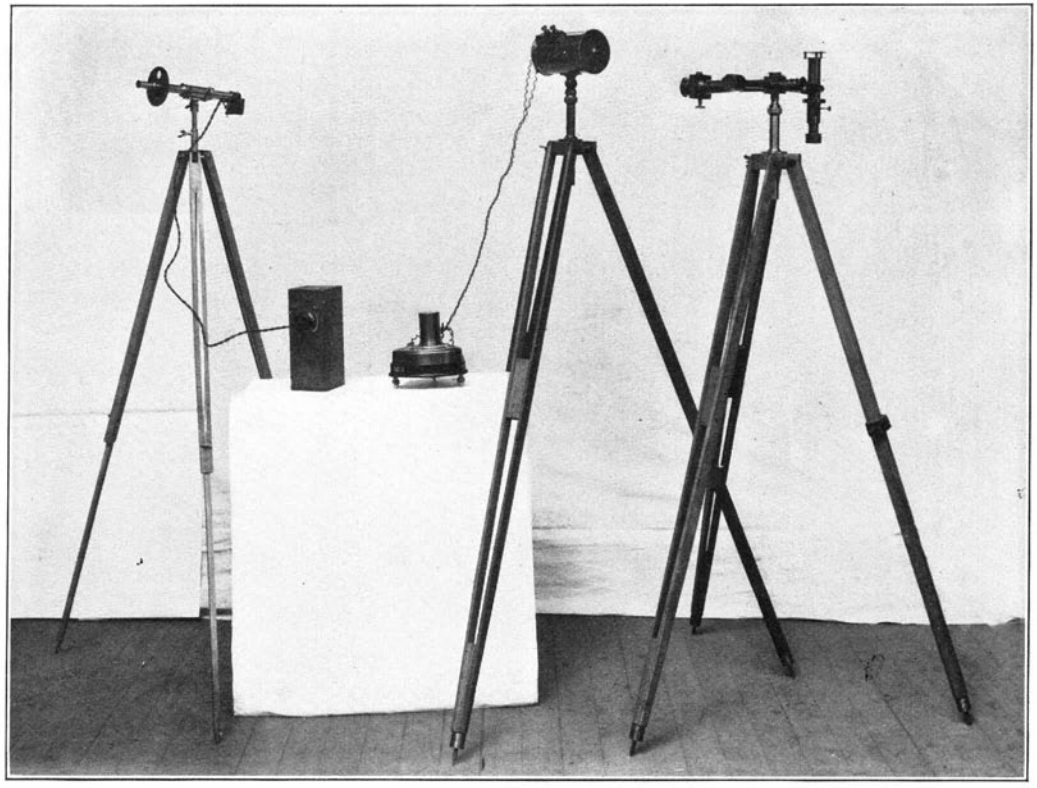


FIG. 8 APPARATUS FOR COLLAPSING BOILER TUBES



THERMO-ELECTRIC PYROMETERS CALLENDAR RESISTANCE PYROMETER

FIG. 9 ELECTRICAL PYROMETERS



WANNER FERY CHATELIER

FIG. 10 OPTICAL PYROMETERS

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7. A large equipment in measuring devices such as extensometers for various uses, autographic recording devices, gauges, etc.

8. A commodious hydraulic laboratory, well equipped with steam engine, steam pumps, centrifugal pumps, standpipe and pressure tanks, lines of piping, measuring pits, tanks, weirs, gauges, meters, motors, etc., giving excellent facilities for testing hydraulic apparatus and for making investigations in hydraulics.

### In the Physics Laboratory

The Physics department is equipped with apparatus enabling it to do the following work in testing and standardization:

1. The testing of boiler tubes for collapse;
2. The checking and calibration of instruments for measuring temperatures;
3. The checking and calibration of electrical standards and instruments;
4. Miscellaneous physical testing.

*The Testing of Boiler Tubes.*—The apparatus available for this work consists of a nickel-steel tube, part of a United States naval gun, capable of withstanding about 20,000 pounds per square inch internal pressure. This apparatus permits of the testing of flues and tubes up to $3\frac{1}{2}$ inches diameter and 10 feet in length for resistance to collapse under external pressure. It is in use at the present time for the determination of a formula for predicting the failure of steel tubes under pressure. Pressures up to 14,000 pounds per square inch may be produced by means of a Cailletet pump, made by the Societe Genevoise, Switzerland. Upon the completion of the work now in progress, the apparatus will be maintained intact for testing at any time the constants of flues and tubes.

*The Checking and Calibration of Instruments for Measuring Temperatures.*—The department has facilities for testing and checking thermometers and pyrometers.* Standard thermometers of the best make, graduated to 0.1° C. and certified by the Reichsanstalt, permit of tests between −25° C. and 250° C. Special con-

*Pyrometers,—Electrical: resistance type, *Callendar recorder with Whipple indicator*, Cambridge Scientific Co., Ltd., Cambridge, England; thermo-electric type, Siemens & Halske, Berlin, Germany; Hartmann & Braun, Frankfort-on-the-Main, Germany; *Bristol*, W. H. Bristol, 41 Dey St., New York City. Optical: *Wanner*, American agents, Eimer & Amend, 205 Third Ave., New York City; *Fery* and *Chatelier*, Ph. Pellin, Paris, France.

stant temperature baths are being made for the convenience and rapid comparison of thermometers.

The equipment for pyrometry is the best obtainable. The department owns a Callendar recorder of the laboratory type and a Whipple indicator with a series of platinum resistance thermometers ranging from 0° C. to 1200° C. In addition to these electric resistance pyrometers, a series of thermo-electric pyrometers is available for checking and testing other pyrometers. The thermo-electric couples with Reichsanstalt certificates are calibrated for temperatures from -180° C. to 1600° C.

The laws of the relation of temperature, light and radiation, have within a few years been studied, so that it is now possible to measure temperatures by optical methods. The equipment in optical pyrometry consists of the Le Chaletier, the Wanner and Fery radiation pyrometers.

For the production of extreme temperatures, both low and high, the department is provided with a liquid-air machine, and with electric furnaces of the arc and of the resistance types. A specially protected constant temperature room has been provided for work of all kinds requiring constancy of temperature.

*Electrical Standards and Apparatus.*—The department owns certified standards of resistance, electromotive force and inductances, and its cabinets contain apparatus of the best make for all electrical and magnetic testing. The Kelvin ampere balances, Weston standard and semi-portable voltmeters and ammeters, and Siemen's electrodynamometers of the department are frequently checked by the potentiometer with standardized resistances and Clark and Weston cells. The laboratory is supplied not only with apparatus but also with piers and conveniences for these tests.

*Miscellaneous Testing.*—Besides the equipment for the work in the three lines indicated above, the department of Physics is supplied for its instructional and research work with standard apparatus of a variety of kinds, all of which is available for testing purposes. Such facilities are standard barometers, standards of length, photometric standards with photometers, standards of weight with sensitive physical balances, a dividing engine and comparator, vacuum and compression pumps with gauges, and various optical apparatus.

### In the Electrical Laboratory

The Electrical Laboratory occupies a separate building and contains an excellent equipment available for many lines of research. It will not be possible to give any detailed description of this equipment but some of the more prominent facilities are mentioned below.

1. In the basement is a storage battery (Gould) of 60 cells each of 240 ampere hours' capacity. This is wired so that all voltages between 2 and 120 can be obtained; also current up to 100 amperes at full voltage, with greatly increased current at lower voltages. This battery is especially adapted to the calibration of electrical measuring instruments, the testing of fuse wire, and to all work where steady current is required.

2. The dynamo laboratory contains very complete arrangements for testing any of the usual types of machines. Power is supplied mostly at 220 volts D. C. and at 440 volts, two-phase A. C., but the transformers permit other usual voltages to be supplied. Several types of variable speed motors, having a speed range from 300 to 1200 revolutions and giving 15 H. P. at any speed, are a recent addition to the equipment. Two general electric stationary armature alternators, capable of connection as either two or three-phase generators or motors and at a variety of voltages, are available. Three rotary converters furnish current based on 110 and 500 volts D. C. An inductor alternator, built by students and designed primarily for variable frequency experiments, may be run at various frequencies up to 150.

There are also switchboards for the rapid handling of apparatus; numerous lamp banks for resistance; a small electric welding machine; various types of arc lamps, permitting experiments in lighting; inductances, condensers, and a large range of measuring instruments of all kinds.

3. A laboratory for the study of illumination is equipped in connection with the photometer rooms. Shades like wall maps line the walls, whereby a light or dark effect can be obtained. This room is lighted by both ceiling and bracket fixtures. Two photometers are available for testing globes and shades as well as lamps of various types. The efficiencies of different types of shades have been studied, also the flickering effect of alternating lighting. Some interesting developments have been made in curved coherers for space telegraphy.

4. A telephone laboratory of two rooms permits experiments in telegraphy and telephony. Experiments now in progress seem to show the availability of high-tension wires for the transmission of telephone messages, obviating the need for separate telephone wires on power lines. Some improvements in long-distance telephony are being tested.

5. An electric test car is also a part of the equipment. This is an interurban type of car, built by the Jewett Car Company, and equipped with the latest type of multiple-unit control 500 volt D. C. motors, by the Westinghouse Electric and Manufacturing Company. One end of the car contains the switch group operated by compressed air, and also the measuring instruments for determining voltage, current speed and acceleration. The car has four 50 H. P. motors, double trolley and controllers at each end of the car, and the usual equipment of head lights, air brakes, heaters, etc.

With this car determinations of the power required for the hauling of coal on electric roads are in progress, and a comparison will be made with the results of dynamometer car tests on steam roads. Traction experiments on a large scale are possible through the courtesy of the Illinois Traction System, whose line passes through the University grounds. The recent equipment of the electric test car of 200 H. P. with recording electric instruments will allow the determining with considerable accuracy of the power required to operate at different speeds and over different grades and curves. A subject of investigation will be the normal highest speed that corresponds to a given radius of curvature, from which it will be possible to determine how much a sharp curve will retard a car.

## VI. The Industrial Interests of Illinois

The state of Illinois is singularly favored in all the conditions requisite for a rapid and permanent industrial development. It has a vast area underlaid with productive coal seams, which afford an abundant supply of bituminous coal of good quality. With the Great Lakes on the northeast, the Mississippi river on the west, and with a network of railroads having an aggregate length of nearly 12,000 miles, facilities for transportation are unexcelled. Illinois is also fortunate in its large area of arable land of extreme fertility. In view of its cheap and abundant fuel and its unex-


FIG. 11 ELECTRIC TEST CAR

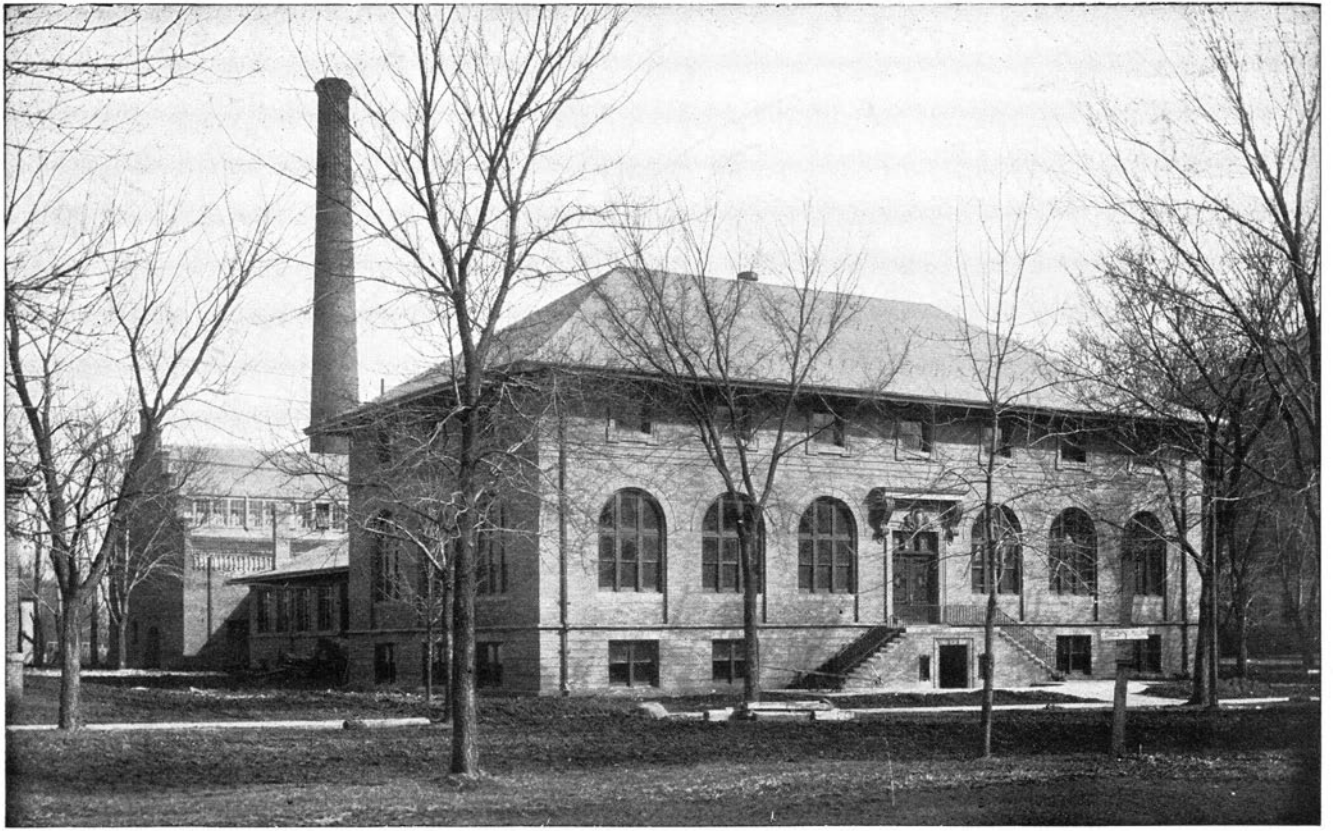


Fig. 12 Electrical Engineering Laboratory
Built in 1897

celled facilities for the transportation of raw material and finished products, it is not surprising that Illinois has pushed forward rapidly in manufacturing and allied industries. Since 1850 the growth of manufacturing in Illinois, measured by the value of the manufactured product, has been at an average rate of one hundred per cent a decade, and the rank of the state has advanced from fifteenth to third. This rate of advance is typical of the development in other industrial lines.

The industrial interests of Illinois may be grouped in four chief classes:

1. Agriculture
2. Coal and Mining
3. Transportation
4. Manufacturing

Of the five million inhabitants of Illinois, more than one-third are engaged in remunerative occupations. A rough idea of the distribution of workers among the industrial pursuits outlined above may be gathered from the following statement. According to the census of 1900, the working population of Illinois may be divided into four nearly equal parts, one of which is engaged in agricultural pursuits; one, in manufacturing; one, in trade and transportation; the last, in domestic and professional service. In the following pages the various industrial interests will be considered somewhat in detail.

*Agriculture.*—In the value of agricultural products, Illinois ranks second, having been exceeded in 1900 by Iowa. The value of agricultural products for 1900 was $345,650,000. This is slightly less than 28 per cent of the value of manufactured products for the same year. From the nature of things, the value of agricultural products after reaching a certain stage can increase but little, while there is practically no limit to the value of manufactured products. Hence while Illinois will always hold high rank in agriculture, its preeminence in the future will be due to its manufacturing and transportation industries.

*Coal.*—The coal deposits of Illinois are included in the eastern interior coal field of the United States, which covers western Indiana, nearly the whole of the state of Illinois, and western Kentucky. Illinois has the largest coal-bearing area of any state in the Union, about two-thirds of the state, or upwards of 37,000

square miles, producing coal. A medium grade of bituminous coal is mined, suitable for the production of power, being used mostly as a steaming fuel by railroads and manufactories.

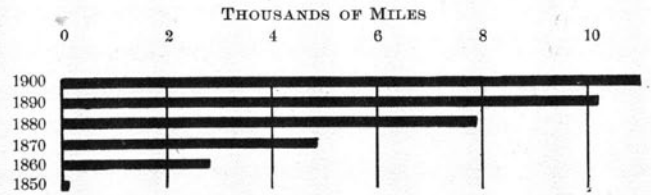
Outside of Pennsylvania, which is preeminently the first state in coal mining, Illinois leads in the production of coal, yielding about one-eighth of the entire quantity mined in the United States. The following table shows the production of coal in the leading coal states during 1902 and 1903:

PRODUCTION OF BITUMINOUS COAL IN THE UNITED STATES

| Rank | State | 1902 | 1903 | Increase Per Cent |
|---|---|---|---|---|
| 1 | Pennsylvania | 98,946,000 | 103,000,000 | 4 |
| 2 | Illinois | 30,031,000 | 34,955,000 | 15 |
| 3 | West Virginia | 26,162,000 | 26,882,000 | 2.7 |
| 4 | Ohio | 23,929,000 | 24,573,000 | 2.6 |
| | United States | 258,372,000 | 277,077,000 | 6.7 |

The following statistics for the year ending June 30, 1903, will give an idea of the magnitude and importance of the coal industry in Illinois: During that year there were 935 mines in operation, giving employment to 35,000 miners and 15,000 employees other than miners. The total product was 35 millions of tons, valued at more than 36 millions of dollars at the mines.

*Railroads.*—In the aggregate of its railway mileage, Illinois holds first rank among the states of the Union, although Texas is a close second. The rapid development of railroads in Illinois is doubtless due to some extent to the early establishment of Chicago as a distributing center of eastern products to the west and southwest. Chicago became the outlet of the traffic by way of the Great Lakes, and when the era of railroad building succeeded, naturally became a great gateway between eastern and western trunk lines. As a result, Illinois is traversed by railroads in all directions. The accompanying charts show the growth of mileage in Illinois since 1850 and the mileage in several states.




MILEAGE GROWTH OF ILLINOIS STEAM RAILROADS

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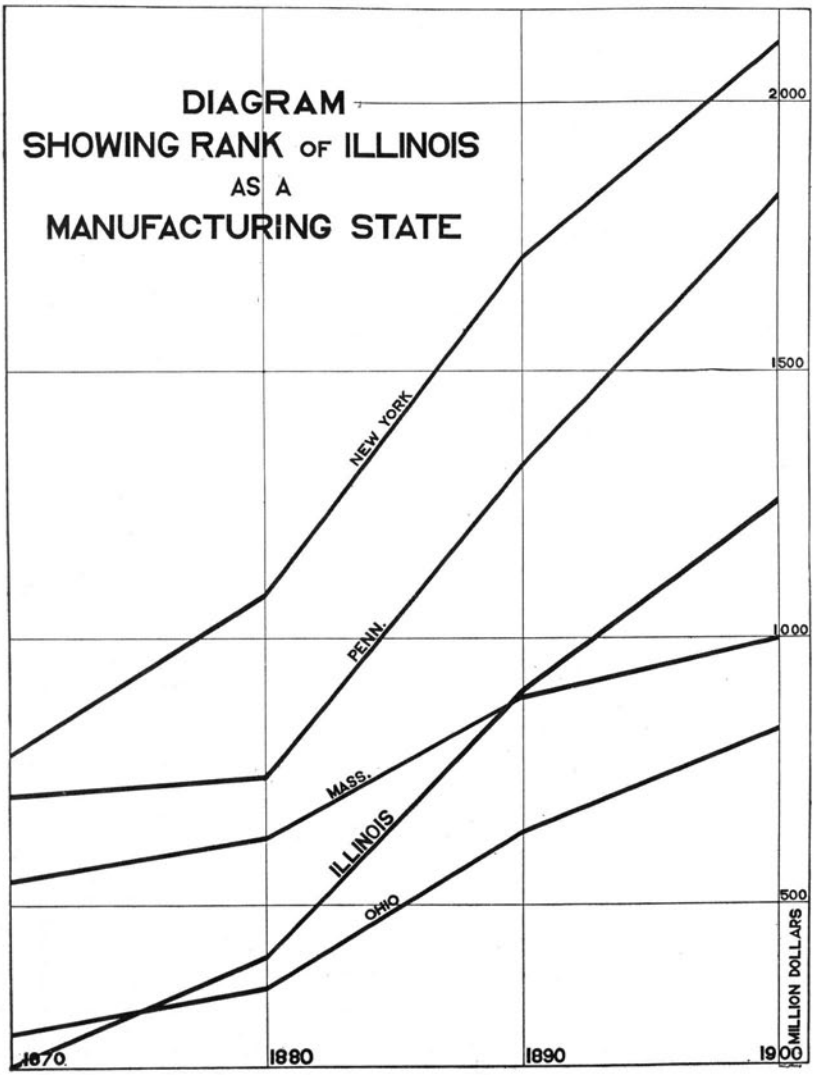
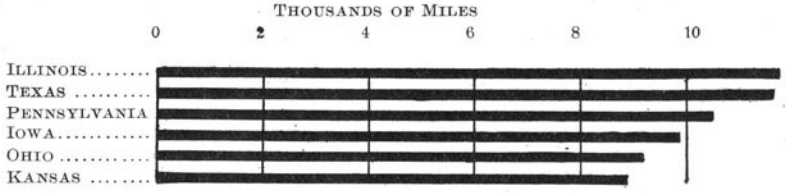


DIAGRAM
SHOWING RANK OF ILLINOIS
AS A
MANUFACTURING STATE
2000
1500
1000
500
MILLION DOLLARS
NEW YORK
PENN.
MASS.
ILLINOIS
OHIO
1870
1880
1890
1900




STEAM RAILROAD MILEAGE IN SEVERAL STATES—1904.

The magnitude of the railroad industry in Illinois is evidenced by the car construction and repair bill. Thus in the statistics for manufactures for 1900, the items for cars and general shop construction, and repairs by steam and street railroad companies aggregate nearly $18,000,000.

In the mileage of street and electric railroads, Illinois is as yet somewhat behind some of the eastern states. In 1903 the mileage of street and electric railroads in several leading states was as follows:

| | |
|---|---|
| Massachusetts | 2037 |
| Pennsylvania | 2001 |
| Ohio | 1858 |
| New York | 1822 |
| Illinois | 993 |

It is significant, however, that the wave of development in electric railroads is sweeping westwards. In the last two or three years, great progress has been made in Ohio, Michigan and Indiana. Illinois has only fairly started in the building of interurban railroads, and the next ten years will doubtless witness a development along this line that will place it well towards the first rank.

*Manufacturing.*—In the value of manufactured product, Illinois at present ranks third among the states of the nation. The accompanying diagram shows the relative position for several decades of the five foremost states in manufacturing. The rapid rate of increase in the case of Illinois is worthy of attention.

Statistics for 1900 showed a total value of manufactured product of $1,260,000,000, an increase of nearly 40 per cent over the figures for 1890. The following table gives data selected from these statistics relating to leading industries somewhat allied in character to engineering:

| INDUSTRIES | WAGE EARNERS | WAGES IN MILLIONS | VALUE OF PRODUCT IN MILLIONS |
|---|---|---|---|
| Agricultural implements..... | 18,231 | 9.06 | 42.0 |
| Cars, shop constructions and repairs steam railroads..... | 13,803 | 8.29 | 16.6 |
| Cars, steam railroads, not including operations of railroad companies | 9,314 | 5.36 | 24.8 |
| Electrical apparatus and supplies... | 6,048 | 2.82 | 12.2 |
| Foundry and machine shop products | 31,851 | 16.88 | 63.9 |
| Iron and steel ..... | 16,642 | 9.64 | 60.3 |
| Vehicles (bicycles, carriages, etc.)... | 9,300 | 4.40 | 18.0 |

In 1900 the number of manufacturing establishments in Illinois was 38,360, and the total number of people engaged in manufacturing was nearly 400,000. The wages paid amounted to $192,000,000, or nearly $500 per person employed. The value of the product, as has been stated, was $1,260,000,000. The total manufactured product for 1905 was probably over $2,000,000,000, an increase of sixty per cent in five years, which may be compared with the increase of forty per cent in the preceding ten years. In view of the present rate of increase in manufacturing, it seems not unlikely that in another decade, Illinois will be a sharp rival of New York and Pennsylvania for first rank.

## VII. What Work Can The Engineering Experiment Station Do That Will Aid The Industrial Interests Of Illinois?

For a number of years the agricultural industry of the state of Illinois has been greatly benefited by the work of the Agricultural Experiment Station. During the first years of its existence, this experiment station was supported by the United States goverment in accordance with the provisions of what is commonly known as the Hatch Act, approved by Congress March 2, 1887.

Subsequently, the increasing demands upon the station for investigations of various kinds rendered additional funds necessary, and the state was called upon for assistance. At present, the Agricultural Experiment Station receives regular support from the state at the rate of about $85,000 per annum. The bennefits to agriculture resulting from the investigations of the station are too well known to need comment. The expenditures of the state in support of the station have been repaid many times. Millions of dollars have been added to the wealth of Illinois through the investigations on corn breeding, the soil surveys and fertility experiments, and the work of eradicating insect pests.

It is the hope of the station staff that the Engineering Experiment Station may stand in the same helpful relation to the great mining, transportation and manufacturing interests of Illinois. What has been done for agriculture may well be done for manufacturing. The state's investments in the Agricultural Experiment Station have been rewarded with large dividends in the way of increased soil fertility and increased and improved agricultural product. Surely as large dividends await similar investments in the Engineering Experiment Station. Important problems in agriculture have been and are being successfully solved by the Agricultural Experiment Station. Important and difficult problems of engineering confront the manufacturer and power user, and press for solution. It is the aim of the Engineering Experiment Station to assist in the solution of these problems, and thus to aid and uplift the engineering industries of Illinois. It may be well to call attention here to the rapidly increasing popularity and value of the work of the Royal Testing Laboratory, located at Charlottenburg, Germany, which has been doing for the German Empire work similar in some details to that which it is now proposed shall be done by the Engineering Experiment Station.

In the following paragraphs are discussed somewhat in detail the lines of work that may be taken up for the benefit of certain industrial interests.

*Fuel.*—The fuel supply of Illinois is of prime importance in its industrial development, and no effort should be spared in the introduction and promulgation of improved methods and processes in the production and consumption of coal. From broad economical considerations, wasteful methods of using coal, or the rejection of any combustible part as waste, are to be discountenanced. Exhaustive and careful experiments will be required before the best conditions can be attained. These experiments must include analyses of coals from all parts of the state, a determination of the best kinds of coal for specific purposes, best methods of burning Illinois coals, effects of various methods of preparation, experiments on various kinds of furnace construction, etc.

*Generation and Use of Power.*—Along the line of power production there is opportunity for much investigation. New problems are confronting both the builders and users of steam and gas motors. There is at present a noteworthy drift from the recip-

rocating engine to the steam turbine. Gas engines of large power have recently been installed, and the development of this type of motor bids fair to be more rapid in the near future. Still newer types of motors are being proposed from time to time, the gas turbine being one that at present occupies much attention as an attractive possibility.

It is evident that the Experiment Station may be of considerable service in this line of work. For the user of power, it can investigate questions relative to the economy of various types of power installations with given conditions of service. For the builder of motors it can investigate the new and perplexing problems that have arisen. The properties of the various fluids used in heat motors need careful study. Superheated steam is essential to the proper working of a steam turbine, yet little is known of its properties. The properties of ammonia and other fluids used in refrigeration are not known accurately, and even the properties of saturated steam are based on Regnault's experiments made nearly seventy years ago. A careful investigation of the properties of heat media of all kinds, extending if necessary over a series of years, would furnish data of the greatest value to engineers, and would in addition be a noteworthy contribution to science.

*Railroads.*—Considerable work for the railroad interests has already been done by the railway mechanical engineering department of the University. The dynamometer car owned jointly by this department and the Illinois Central Railroad has been used in numerous road tests, and these tests have been used as a basis for the computation of tonnage ratings. This work will be prosecuted vigorously under the direction of the new department of railway engineering and administration recently organized.

Other problems relating to design, maintenance of way, etc., will be attacked as they arise. The question of electric traction is becoming one of great importance in Illinois. The electrical engineering department has recently added to its equipment a new dynamometer car, with which tests may be made on electric lines, and it is expected that these tests will furnish valuable data.

*Manufacturing and Building.*—It is expected that the Experiment Station will prove helpful to the manufacturing and building interests of Illinois in several ways. In the first place, it will supply accurate data regarding the properties of the materials used in engineering structures and buildings. The new lab-

oratory of applied mechanics with its extensive equipment furnishes ample facilities for this line of work. The new 600,000-pound vertical testing machine permits the testing of full-sized specimens 24 feet in length. The reinforced concrete tests now in progress show the possibilities in this line of work. In the near future, an extensive series of tests on cast-iron columns, and others on steel plates are contemplated. A considerable portion of the available funds of the station will be expended in this work of testing materials. Secondly, the Experiment Station will investigate manufacturing processes. As an example of this line of work, the high-speed steel tests are cited. Thirdly, problems relating to design and construction will be studied, and all useful results will be published for the benefit of those engaged in design or construction.

As a rule the Experiment Station will undertake only such investigations as will lead to results of fundamental importance, results that will be helpful to a large class of engineers or manufacturers. It will not, in general, undertake work of importance to individuals only, e. g., the testing of a device or invention for the sole benefit of the inventor.

Those in charge of the Engineering Experiment Station feel that if the work of the station be carried out along the lines here suggested, and if proper support be afforded by the state in order that the work can be so carried out, the engineering industries of Illinois will receive benefits which will amply repay all expenditures.

## VIII. Cooperation

It is very essential that great care should be exercised in the selection of subjects to be investigated. It is equally important that the results of the investigations should be published in such shape as will best serve the purposes of engineers and manufacturers. In order that these ends may be attained it has been thought desirable that there shall be organized several committees of conference on matters of widespread interest. One such committee has already been appointed, the Conference Committee on Fuel Tests, composed of representatives appointed by the following Illinois organizations: State Geological Survey, Western Society of Engineers, Building Managers' Association of Chicago, Western Railway Club, Illinois Manufacturers' Association, Illinois Coal Operators' Association, State Electric Light Association,

Board of Trustees University of Illinois, and the State Engineering Experiment Station. It is planned to form similar committees relating to other lines of work whenever the importance of the investigations warrants it. It is hoped that suggestions may be proposed to the station from engineers, or from mining, railway, or manufacturing interests, to the end that the work of the station may grow to be of real value to the commercial interests of the state. Engineering societies will find at the University excellent facilities for meeting, and it is suggested that such societies plan to hold their meetings here as often as possible.

The desirability of cooperating with similar state experiment stations or with some of the national departments having charge of tests of fuel, timbers, structural materials, or with water surveys, etc., is also evident, and such cooperation will be sought whenever mutual good is promised. Such a method will often tend to concentrate isolated and scattered efforts, and will also tend to standardize methods of tests and forms of reports and specifications.

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## Publications Of The Engineering Experiment Station

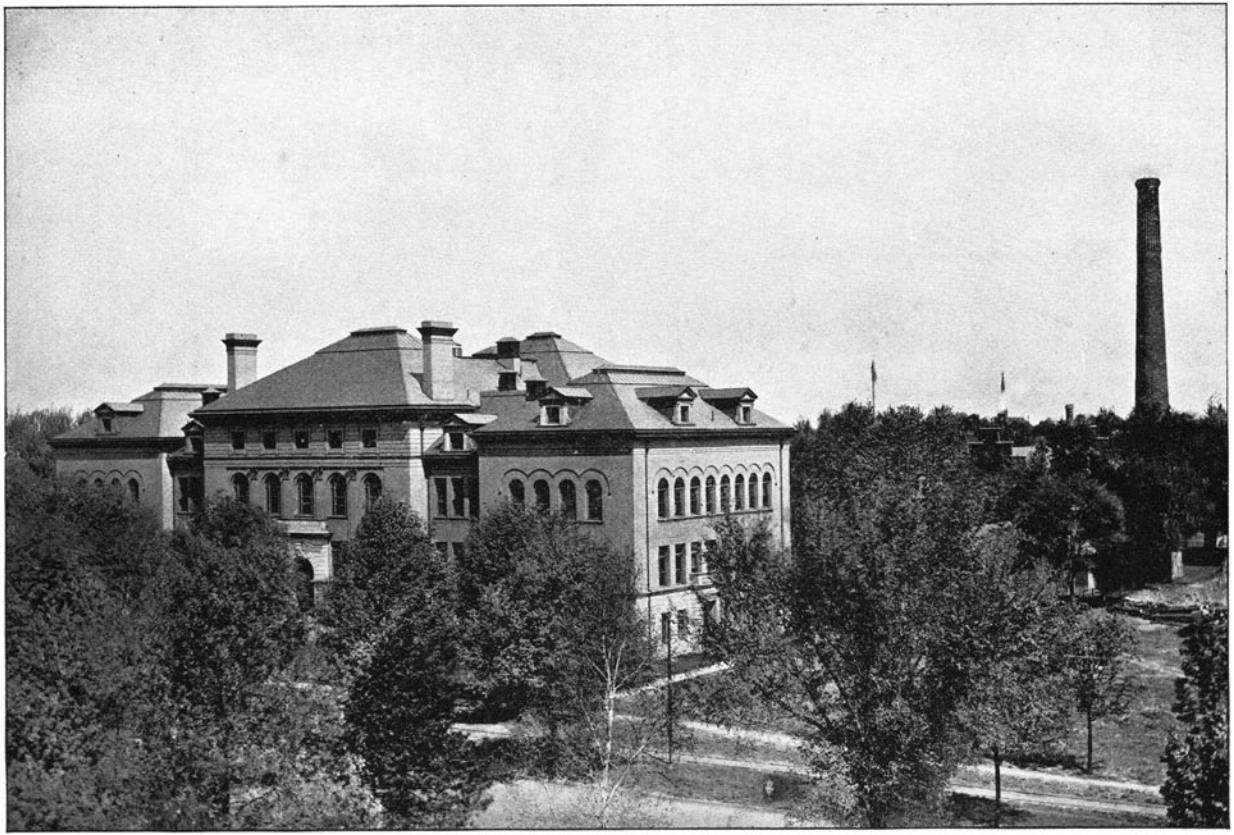
*Bulletin No. 1.* Tests of Reinforced Concrete Beams, by A. N. Talbot. 1904.

*Circular No. 1.* High-Speed Tool Steels, by L. P. Breckenridge. 1905.

*Bulletin No. 2.* Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and Henry B. Dirks. 1905.

*Circular No. 2.* Drainage of Earth Roads, by Ira O. Baker. 1906.

*Bulletin No. 3.* The Engineering Experiment Station of the University of Illinois, by L. P. Breckenridge. 1906.



Engineering Building
Built in 1894

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